

Real-Time Simulation of Very Closely Spaced Parallel Runway Approaches

Greg Trott
Raytheon Company
Network Centric Systems
Marlborough, MA

Debbi Ballinger
Gordon Hardy
Sandy Lozito
Ramesh Panda
Savita Verma
NASA
Ames Research Center
Moffett Field, CA

Agenda

- TACEC Background
- Simulation Overview
- Simulation Results
- Next steps

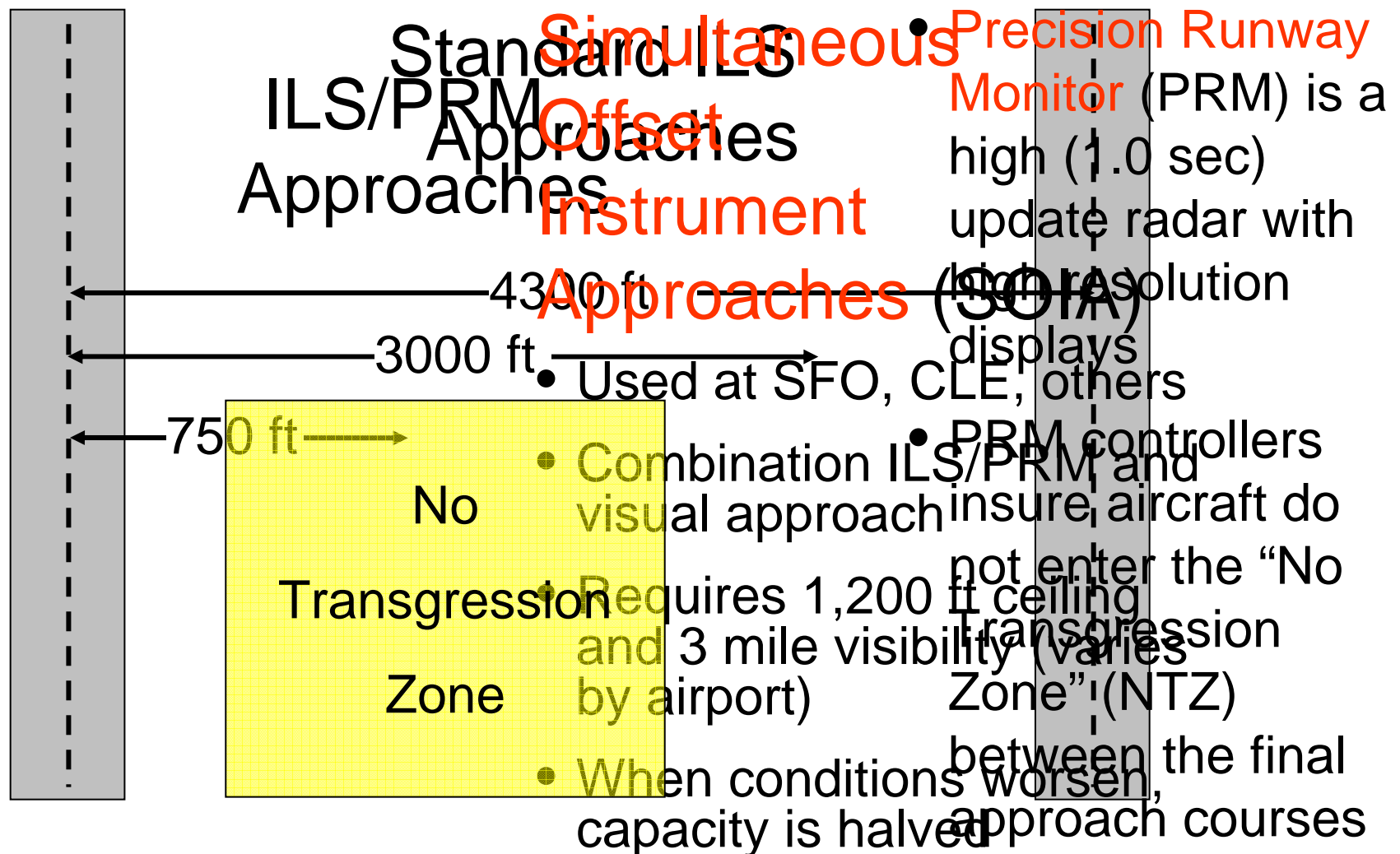
Terminal Area Capacity Enhancement Concept (TACEC)

■ Motivation

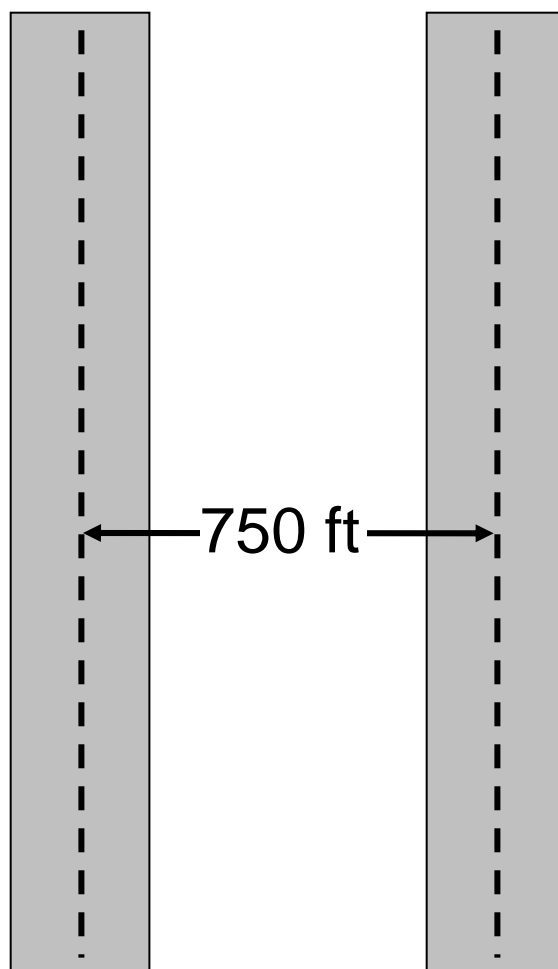
- Volume of air traffic is expected to **double** in the next 10-15 years
- Runway operations are a major constraint
- A fundamental limit on runway operations is In-Trail spacing required for wake vortex avoidance
- With today's separation requirements, adding new runways at major airports is expensive or impossible
- Existing procedures for Very Closely Spaced Parallel Runways (VCSPR) limit operations to VFR and marginal conditions

TACEC has a solution!

Today's Parallel Runway Operations



TACEC Benefits



- Enables paired arrivals and departures on runways with 750 ft centerline spacing in all conditions up to and including CAT-III
- Highly accurate and predictable arrival times through use of 4D trajectories and advanced navigation and guidance systems
- Capacity increases achievable in “all weather” conditions by adding new runways within existing airport footprint

TACEC Approach Highlights

Once separation reaches 1nm, follower's **autopilot couples** with leader to precisely maintain spacing during final approach

Aircraft approach reaches 1nm, **for pairing** follower's **autopilot** performs direction, leader to precisely relative timing criteria

Initial route segments safely **stage aircraft for alignment** at the coupling point

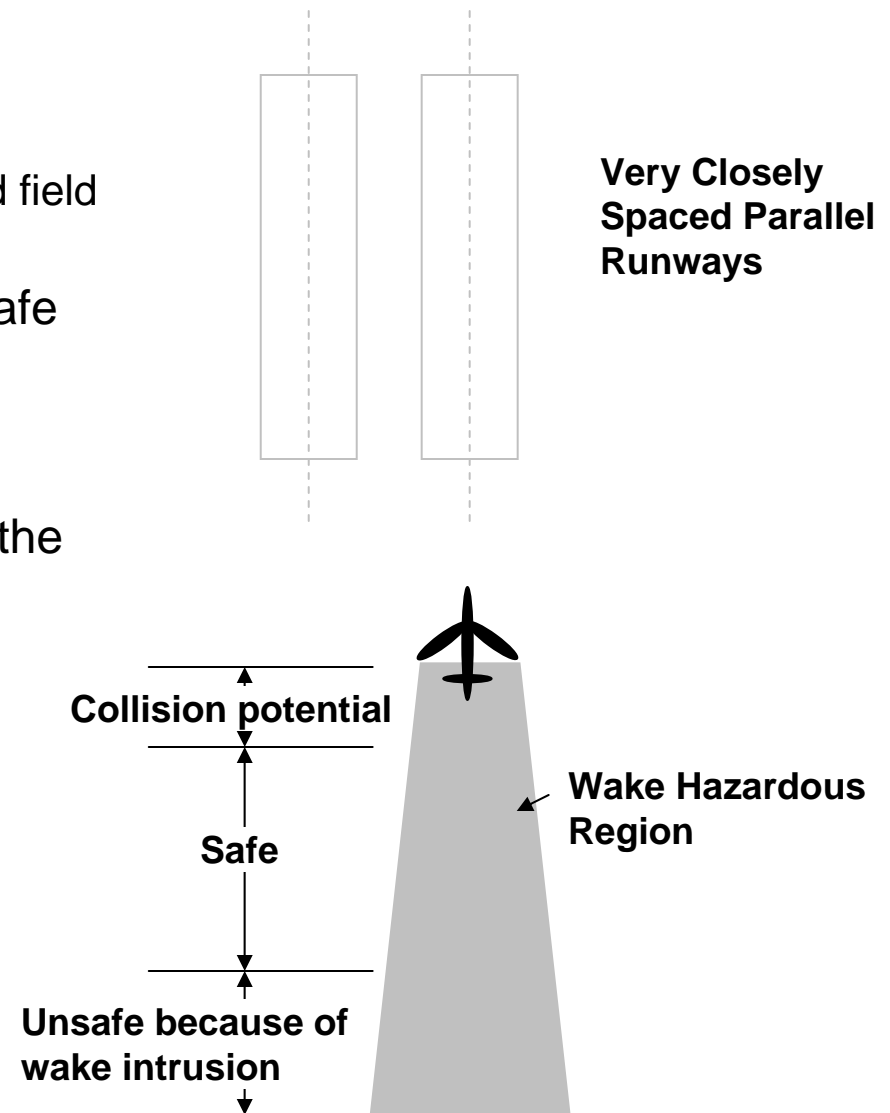
Aircraft use **differential GPS-enabled, high-precision FMS** capable of executing 4D trajectories

Ground-based processor generates and **assigns 4D trajectories** to each aircraft (via data-link)

processor
the aircraft
approximately 30 minutes
pace

Parallel Approach System Requirements

- Strategic Safe Zone Prediction
 - Defines safe zone size and position
 - Considers aircraft characteristics and wind field
 - Based on work by V. Rossow (NASA)
- 4D guidance requirement to merge into safe zone by the coupling point
 - Required Time of Arrival (FMS)
 - Relative Positioning
- Coupled guidance requirement to stay in the safe zone



Simulation Overview

- Part of NASA's **Virtual Airspace Simulation Technologies (VAST)** Project
- Performed in the **SimLabs** facility at Ames Research Center
- Goals
 - Accelerate development of a far-future concept through **early implementation**
 - Assess **viability** and **acceptability** of TACEC
 - Real-time, **human-in-the-loop** simulation
 - Human-factors studies of prototype **displays** and concept **procedures**

Crew-Vehicle Systems Research Facility (CVSRF)

Advanced Concepts Flight Simulator (ACFS)

Experiment Control Stations



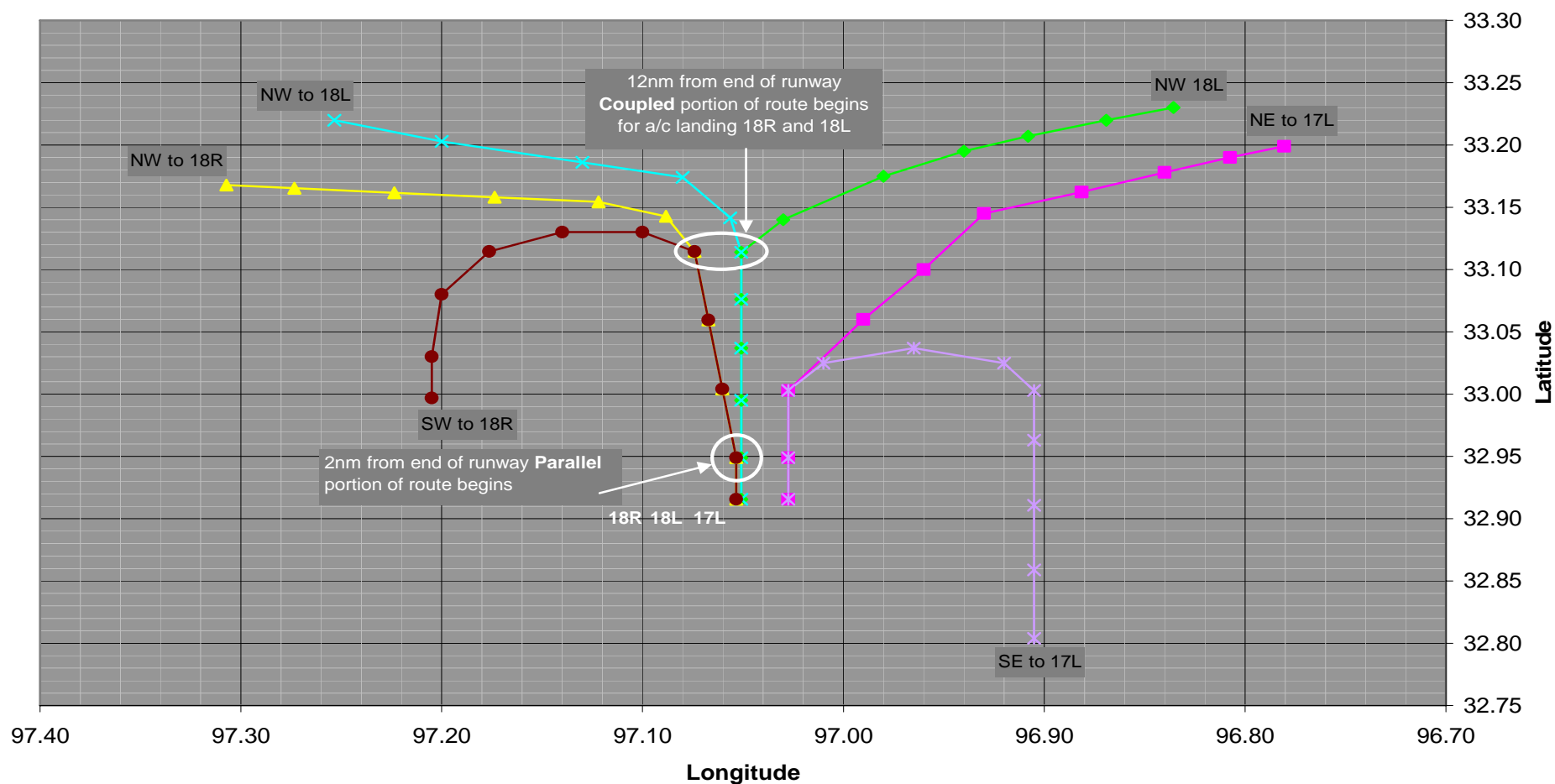
ACFS Cockpit



- Six degree-of-freedom motion
- 757-like ownship
- Integrated prototype Primary and Navigation Displays
- Pre-recorded, 747 traffic aircraft

Simulation Routes

Configuration 1 - Arrival Routes for flying a total of 25 nm on each route



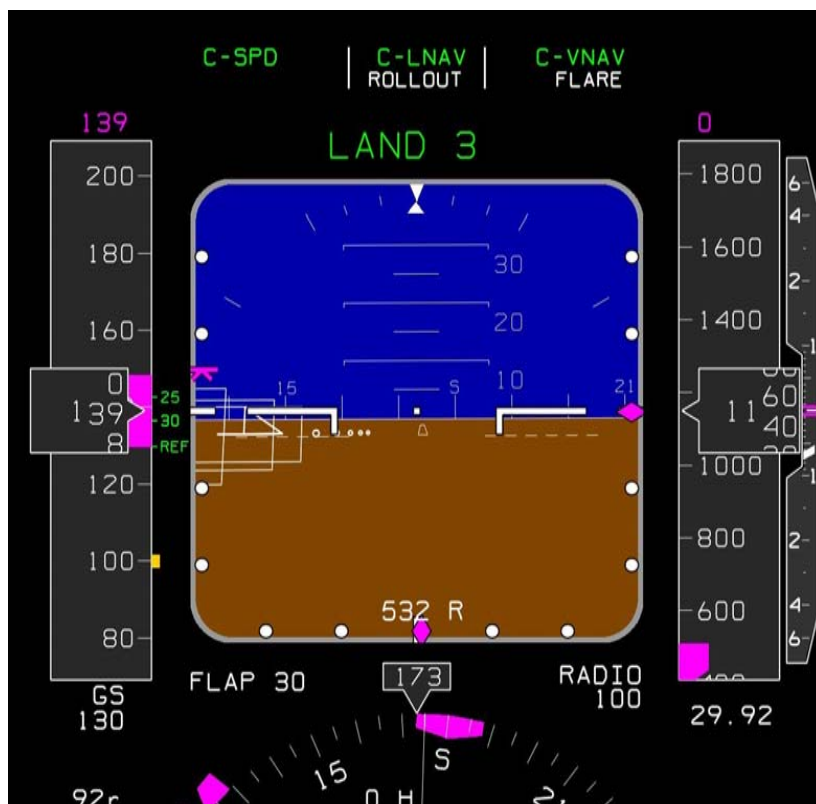
◆ NW 18L
 ■ NE to 17L
 ▲ NW to 18R
 × NW to 18L
 ✱ SE to 17L
 ● SW to 18R

Example Scenario



- Conceptual airport (SRT) = modified DFW
- Leader (B747)/Ownship (B757) approaching 18L/R - 750' separation
- Ownship receives leader's position and speed through ADS-B
- 4D clearance to the coupling point (e.g. COIN1)
- Ownship engages closed loop speed control at the coupling point
 - About 12 NM from touchdown
 - Six degree offset to 2 nm from touchdown
 - 5 or 10 second longitudinal separation
- Steady, adverse crosswind

Ownship CDTI Displays on Final



Primary Flight Display



Navigation Display

- Highly conservative prediction of the hazardous wake area location based on aircraft characteristics, turbulence, and cross-wind
- Traffic position and wake hazardous area added on both displays
- PFD field of view doubled
- NAV zooms in to 1/4 mile scale
- Five predictor dots (2 seconds each) added for both aircraft
- Ownship Longitudinal Situational Indicator, **LSI**, added to both displays (750'/dot on PFD)

Simulation Details

- Test subjects: Retired commercial pilots
- Nearly completely automated approach and landing
 - Pilot responsible for approving engagement of coupling, monitoring safe progress
 - All other functions (speed brakes, flaps, gear deployment) automated
- Variables
 1. Visibility
 - Clear
 - Low (Cat-IIIB)
 2. Commanded longitudinal separation
 - 5 seconds
 - 10 seconds
 3. Ownship route/wind direction
 - East side (straight-in), wind from the west
 - West side (slewed), wind from the east
- Blunder decision case presented for discussion

Emulated 4D Flight Management System

The Flight Management System (FMS) in the ACFS was modified to emulate a 4D-capable FMS

- Pre-existing system was a simulated 3D FMS
- TACEC routes were defined as a series of waypoints
- Continuous Descent Approaches with speed and altitude constraints placed at the coupling point
- Near the coupling point, a speed control algorithm was activated to maintain spacing with lead
- Automated deployment of speed-brakes, flaps and gear

Preliminary Pilot Survey Results

1. Wake display and LSI were useful tools that pilots used to maintain their situational awareness. They preferred the depiction of wake on ND, and LSI on PFD.
2. Pilots used the zoom capability up to 1/4th of the mile to maintain a tactical view of the situation.
3. Pilots would like to use the acknowledgement button to arm coupling prior to engagement at the coupling point.
4. Pilots were more comfortable with VCSPR approaches and automation in VFR rather than CAT-IIIB visibility conditions.
5. Pilots preferred 10s versus the 5s spacing between the lead and follower aircraft.
6. Pilots would like to be able to deploy gear and influence speed and flaps without disengaging auto pilot. Automation should cue the pilots on engaging the gears and flaps, to achieve precision.
7. All the pilots were concerned about breakout procedures, and think automation will play a large role in the determination of the procedures, with some help from air traffic control.

Summary

Completion of the simulation achieved:

- Refinement of the TACEC concept including further definition of airspace and operations requirements
- Data on human factors issues associated with using VCSPRs within 25 miles of the airport
- Creation of an airport designed specifically for VCSPR research
- An implementation of VCSPR technology into the ACFS simulation software
- Integration of display technology into the ACFS that can be used for future VCSPR work

Future Work

- Breakouts/blunders
 - Definition of routes and possible refinements to airspace to accommodate breakouts
 - Addition of breakout cues to the cockpit displays
 - ATC involvement in breakout maneuvers
- Development of real-time trajectory synthesis
- Inclusion of other traffic
- Improvement of 4D FMS
- Additional human factors studies (workload, performance, etc.)

Acknowledgements

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Questions?